# THE EFFECT OF BALANCED AND UNBALANCED CONDITIONS OF NITROGEN AND PHOSPHORUS OF THE SOIL ON THE QUANTITY AND QUALITY OF PROTEIN IN CORN GRAIN

BY

JOHN NEWTON CARTER

B.S., University of Missouri, 1943
M.S., University of Illinois, 1948

## AN ABSTRACT OF A THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN AGRONOMY
IN THE GRADUATE COLLEGE OF THE
UNIVERSITY OF ILLINOIS, 1950

URBANA, ILLINOIS

1950

# THE EFFECT OF BALANCED AND UNBALANCED CONDITIONS OF NITROGEN AND PHOSPHORUS OF THE SOIL ON THE QUANTITY AND QUALITY OF PROTEIN IN CORN GRAIN

BY

JOHN NEWTON CARTER

B.S., University of Missouri, 1943
M.S., University of Illinois, 1948

AN ABSTRACT OF A THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN AGRONOMY
IN THE GRADUATE COLLEGE OF THE
UNIVERSITY OF ILLINOIS, 1950

URBANA, ILLINOIS

1950

ACKNOWLEDGEMENTS

The author wishes to express his appreciation to Doctor E. B. Earley for his invaluable advice and counsel throughout all phases of this investigation.

The assistance of Mrs. Joan Rheumer in the laboratory analyses is gratefully acknowledged.

This work was supported by a cooperative gift fund from Funk Bros. Seed Co. of Bloomington, Illinois and the Corn Industries Research Foundation.

R. UNIV. BIBLIOTHEEK LEIDEN

# THE EFFECT OF BALANCED AND UNBALANCED CONDITIONS OF NITROGEN AND PHOSPHORUS OF THE SOIL ON THE QUANTITY AND QUALITY OF PROTEIN IN CORN GRAIN

## Introduction

Corn protein, within recent years, has decreased from 1 to 2 per cent in the corn grain as a result of the decrease in soil fertility and the selection of hybrids for greater yield rather than protein content. Previous studies made have revealed that corn protein has been increased through plant breeding and soil fertility. The alcohol soluble nitrogen in the corn kernels was found to be increased at a much faster rate than the other nitrogen fractions with the increase in protein. The alcohol soluble nitrogen has been shown to be deficient in two indispensable dietary amino acids, tryptophane and lysine, and therefore, has a low biological value. The object of this experiment was to study the effects of balanced and unbalanced conditions of nitrogen and phosphorus of the soil on the quantity and quality of the protein in the corn grain.

## Materials and Methods

The experimental field was laid out in an area which had been heavily cropped without fertilization and had a very low content of nitrogen and phosphorus in the soil. The nitrogen fertilizer was applied at the rate of 0, 80, 160, and 320 pounds of nitrogen per acre in strips across the field and the phosphorus fertilizer was applied at the rate of 0, 20, 80, 160, and 400 pounds of $P_2O_5$ per acre in strips transverse to the nitrogen fertilizer strips giving a checkerboard arrangement for the nitrogen and phosphorus fertilizer plots. Two corn hybrids, Illinois High Protein and G-94 which differ widely in their genetic ceilings for protein synthesis, were planted adjacent to each other across the fertility plots at the rate of 3 per hill

checked every 40 inches. Grain samples were taken at mid-pollination, 2, 4, 6, and 8 weeks after mid-pollination and frozen in the field and later dried in the laboratory using the lyophiling technique. The mature grain samples in their natural dry state were taken from the field and brought into the laboratory for analysis. Chemical data included total nitrogen, nitrogen fractionation, total phosphorus, phosphorus fractionation, and per cent oil on both the immature and mature samples.

## Results and Conclusions

1. There was a highly significant increase in yield in both Illinois High Protein and G-94 when nitrogen and phosphorus fertilizer were applied to the soil. The main increases in yield were due to the increase in nitrogen of the soil. Phosphorus fertilizer increased the yield at the highest level of phosphorus fertilizer and on the highest level of nitrogen fertilizer where it balanced the effect of the excess nitrogen. The increased yield was reflected in the following ear characteristics: (a) increase in the length and diameter of ears, (b) increased weight per 100 kernels, (c) increased number of plants bearing ears, and (d) increase in the shelling percentage.

2. The nitrogen content of the immature kernels of Illinois High Protein and G-94 was found to be high at mid-pollination followed by a decrease to the 4 to 6 week period where the nitrogen content was rather constant to maturity. The plots which had received nitrogen fertilizer had a higher per cent nitrogen in the kernels at all stages of growth than did the plots which had not received nitrogen fertilizer. The milligrams of crude protein per 100 kernels increased from mid-pollination to the 8 week period. There was a slight increase or decrease from the 8 week period to maturity depending on the fertility of the plot. The highest amount of crude protein per 100 kernels was obtained on the plots which had received nitrogen fertilizer. In both per cent nitrogen and milligrams of crude protein per 100 kernels the highest level was reached when both nitrogen and phosphorus were applied in a balanced

condition.

3. The crude protein of the immature kernels of Illinois High Protein and G-94 was largely composed of the water soluble fraction at mid-pollination. The water soluble fraction decreased rapidly between the 2 and 4 week period with a steady increase in the alcohol and alkali soluble fractions. The maximum per cent and percentage of the total nitrogen in the alcohol soluble fraction were reached at the 6 to 8 week period and that of the alkali soluble fraction at the 4 to 6 week period. There was a decrease in per cent and percentage of the total nitrogen in these two fractions from the maximum level to maturity with an increase in these values in the insoluble fraction. Through the increase in the nitrogen content of the soil there was, in general, an increase in per cent nitrogen in each fraction. The largest change was in the alcohol soluble fraction where there was a large increase in the per cent and percentage of the total nitrogen. The alkali soluble fraction decreased with the increase in the alcohol soluble fraction at the various stages of growth. The milligrams of crude protein per 100 kernels in each fraction were affected about the same as the per cent nitrogen in each fraction. The greatest increase in the fractions occurred when nitrogen fertilizer was applied, especially in the alcohol soluble fraction. The maximum increases in per cent and milligrams of crude protein in the fractions occurred when nitrogen and phosphorus were applied together.

4. The per cent tryptophane and lysine of immature kernels of Illinois High Protein and G-94 were at their highest levels at mid-pollination. There was a decrease in the per cent tryptophane and lysine from 2 weeks after mid-pollination to maturity. The greatest of these decreases in per cent tryptophane and lysine occurred between the 2 and 6 weeks period after mid-pollination. The percentage of crude protein as tryptophane and lysine decreased from 2 weeks after mid-pollination to maturity. The per cent tryptophane and lysine were higher at all stages of growth in the Illinois High Protein than in the G-94. The per cent methionine in the Illinois High

Protein was at its lowest value at 2 weeks after mid-pollination and increased both in per cent methionine and percentage of crude protein as methionine to maturity. The per cent methionine in the G-94 was at its highest value at 2 weeks after mid-pollination and decreased to maturity. The percentage of crude protein as methionine decreased during this period.

5. The per cent crude protein was increased in the mature kernels of Illinois High Protein and G-94 by the application of nitrogen and phosphorus fertilizer. The main increases in crude protein occurred when nitrogen fertilizer was applied to the soil. The maximum increase in crude protein occurred when both nitrogen and phosphorus were applied to the soil. The main role of phosphorus fertilizer was to balance the excess nitrogen so that the maximum per cent crude protein could be produced. The pounds of crude protein produced per acre followed the same general pattern as the per cent crude protein. There were large increases in pounds of crude protein per acre when nitrogen was applied alone, but the maximum was obtained when both nitrogen and phosphorus were applied in a balanced condition. The milligrams of crude protein per 100 kernels were affected about the same as the per cent crude protein by different levels of soil fertility.

6. There were large variations in the nitrogen fractions of the mature kernels of Illinois High Protein and G-94 through the application of fertilizer. The greatest of these variations occurred when nitrogen fertilizer was applied. There were increases in the alcohol soluble fraction at the expense of the other fractions, especially the alkali soluble fraction of the Illinois High Protein and the alkali and water soluble fractions of G-94. Phosphorus fertilizer had a restraining effect on the total crude protein and therefore, the percentage of the total nitrogen in the alcohol soluble fraction was held down when moderate amounts of nitrogen fertilizer were applied. When heavy applications of nitrogen fertilizer were applied the phosphorus fertilizer increased the crude protein and therefore, increased the percentage of the total nitrogen in the alcohol

soluble fraction. There was a correlation between the per cent and percentage of the total nitrogen in the alcohol soluble fraction and the total crude protein. There was also a correlation found between the percentage of the total nitrogen in the alkali soluble fraction and the percentage of the total nitrogen in the alcohol soluble fraction. The Illinois High Protein had a much higher percentage of the total nitrogen in the alcohol soluble fraction than the G-94 with decreases in the percentage of the total nitrogen in the other fractions. The actual per cent nitrogen in these fractions increased from the G-94 to the Illinois High Protein. There were increases in the milligrams of crude protein per 100 kernels in these fractions through the application of fertilizer. The main increases occurred when nitrogen fertilizer was applied, but the maximum amount was reached when nitrogen and phosphorus were applied in a balanced condition. The main increase in the amount of crude protein in these fractions per 100 kernels occurred in the alcohol soluble fraction.

7. There were variations in the per cent tryptophane and lysine in the mature kernels of Illinois High Protein and G-94 through a variation in the fertility level of the soil. In general, with an increase in the crude protein content of the kernels there was an increase in both the per cent tryptophane and lysine. The increase in crude protein occurred at a faster rate than the increases in tryptophane and lysine; therefore, the percentage of crude protein as tryptophane and lysine was decreased. The Illinois High Protein had a greater per cent tryptophane and lysine than G-94. It was concluded that by increasing the crude protein content by fertilization or by breeding there would be an increase in the per cent tryptophane and lysine. The increases and decreases in tryptophane and lysine were very similar; therefore, the same fractions in the kernels were thought to increase or decrease these amino acids. It was concluded that the increase in these amino acids came from the increase in per cent nitrogen in the more desirable fractions, although the percentage of the total nitrogen in these fractions was decreasing with increas-

ing crude protein content. The per cent methionine remained about constant in the Illinois High Protein under different fertility levels and was increased with increasing crude protein in G-94. The percentage of crude protein as methionine was decreased with increasing crude protein content in both varieties of corn. The per cent methionine was much higher in the Illinois High Protein than in G-94. The percentage of crude protein as methionine was only slightly higher in G-94 than in Illinois High Protein.

8. The endosperm and germ in the mature kernels of Illinois High Protein and G-94 were fractionated to determine the various nitrogen compounds present under different levels of fertility. The alcohol and alkali soluble fractions were the largest and varied to the greatest degree of any fraction in the endosperm. The largest fraction in the germ was the water soluble fraction. The germ nitrogen was rather constant in the percentage of the total nitrogen under different fertility levels. The main variations that occurred under different fertility conditions were in the alcohol and alkali soluble fractions of the endosperm. When the nitrogen content of the soil was increased there was an increase in the alcohol soluble fraction of the endosperm with a corresponding decrease in the percentage of the total nitrogen in the alkali soluble fraction. There were rather constant proportions of the various nitrogen fractions in the germ between varieties. The main variation that occurred between the Illinois High Protein and G-94 was in the proportion of nitrogen in the endosperm. There was a larger proportion of alcohol soluble fraction and a lower proportion of alkali soluble fraction in the Illinois High Protein than in G-94. The increase in the alcohol soluble fraction by fertilization and by breeding seemed to be at the expense of the alkali soluble fraction.

9. The phosphorus content of the immature kernels of Illinois High Protein and G-94 was found to be high at mid-pollination followed by a decrease in the per cent phosphorus at maturity. The plots which had received nitrogen fertilizer had a higher per cent phosphorus in the kernels at the earlier

stages of growth than did the plots which had not received nitrogen. At the later stages of growth the plots which had received phosphorus fertilizer had a higher per cent phosphorus in the kernels than plots not receiving phosphorus. The milligrams of phosphorus per 100 kernels were greater on those plots which had received phosphorus fertilizer. The greatest amount of phosphorus per 100 kernels was accumulated on the plots which had received both nitrogen and phosphorus fertilizers. In both the per cent phosphorus and milligrams of phosphorus per 100 kernels the data showed that the maximum of these values was obtained through a balanced condition for both nitrogen and phosphorus fertilizers.

10. The greatest per cent phosphorus in the phosphorus fractions of the immature kernels of Illinois High Protein and G-94 was in the cold trichloracetic acid fraction. The per cent and percentage of the total phosphorus in this fraction increased to maturity. The per cent and percentage of the total phosphorus in the other phosphorus fractions were rather high at mid-pollination and decreased to maturity. The main variations in these fractions due to the fertility level of the soil occurred in the cold trichloracetic acid fraction. There were variations in the protein and phospholipid fractions at the various stages of growth due to the difference in fertility level of the soil. The milligrams of phosphorus in each fraction per 100 kernels varied about the same as the per cent phosphorus in each of these fractions. The cold trichloracetic acid fraction was, by far, the largest fraction present at all stages of growth. The other fractions were increasing in amount to maturity, but at all stages of growth they were much below that of the cold trichloracetic acid fraction. The milligrams of phosphorus in each fraction per 100 kernels reached their maximum value when nitrogen and phosphorus fertilizers were applied in a balanced condition.

11. The per cent phosphorus in the mature kernels of Illinois High Protein and G-94 was definitely increased by fertilization. There was an increase in the per cent phos-

phorus by the application of phosphorus fertilizer alone. There was an increase in the per cent phosphorus with increasing amounts of nitrogen fertilizer if the phosphorus level of the soil was sufficiently high. The greatest increase in per cent phosphorus was obtained when nitrogen and phosphorus fertilizers were applied together. The greatest amount in milligrams of phosphorus per 100 kernels was obtained on those plots which had received a heavy application of phosphorus fertilizer and moderate amounts of nitrogen fertilizer. When heavy applications of nitrogen were made there was a decrease in the amount of phosphorus per 100 kernels unless heavy applications of phosphorus fertilizer were made to balance the nitrogen fertilizer.

12. The greatest per cent of the phosphorus compounds in the mature kernels of Illinois High Protein and G-94 was composed of the non-protein cold trichloracetic acid fraction with a lesser but still an important per cent in the protein and phospholipid fractions. The greatest variations in the phosphorus fractions under different fertility conditions occurred in the cold trichloracetic acid fraction. The per cent and percentage of the total phosphorus in this fraction were increased when phosphorus fertilizer was applied in sufficient amounts. The lowest percentage of the total phosphorus in the cold trichloracetic acid fraction was obtained on those plots which had received excessive amounts of one or both fertilizers. With a decrease or an increase in the percentage of the total phosphorus in the cold trichloracetic acid fraction there was a corresponding increase or decrease in this value for the protein and phospholipid fractions. The percentage of the total phosphorus in the cold trichloracetic acid fraction was highest on those plots which had received moderate amounts of either fertilizer or a combination of both fertilizers. There was a corresponding decrease in the percentage of the total phosphorus in the protein and phospholipid fractions on the plots which had received moderate amounts of fertilizer. The milligrams of phosphorus in the various fractions per 100 kernels were varied by differences in the fertility level of the

soil. The main variations occurred, as shown by the per cent and percentage of the total phosphorus in the fractions, at the extremes of fertilization. Throughout the center of the field where the fertilizer was applied in a balanced condition, the milligrams of phosphorus in each fraction were rather uniform.

13. Phosphorus of the endosperm and germ in the mature kernels of Illinois High Protein and G-94 were fractionated to determine the various phosphorus compounds under different levels of fertility. In both varieties there were similarities in proportions of the various phosphorus fractions in the endosperm and germ. The greatest per cent phosphorus was located in the germ. The per cent phosphorus in the various fractions was much larger in the germ than in the endosperm. The greatest per cent phosphorus in the endosperm and germ was located in the cold trichloracetic acid fraction. In both varieties the fertility of the soil affected to some extent the per cent and proportion of phosphorus in the various fractions. The percentage of the total phosphorus in the various fractions was rather constant under different fertility conditions. The Illinois High Protein had a greater amount of phosphorus in the various fractions than did the G-94. This was caused by a greater actual per cent phosphorus in the Illinois High Protein.

14. Through the increase in the fertility level of the soil there were large increases in yield, per cent and amount of protein, amount of oil, and a small increase in the per cent oil. Although the alcohol soluble fraction was increasing at the expense of the more desirable nitrogen fractions, it was concluded that the feeding value of the corn grain was increased with an increase in the crude protein content. This takes into consideration the increase of the protein content by both fertilization and breeding. The feeding value would not be increased to the extent of the increase in crude protein, but would be somewhere between the two protein values. With the increase in the fertility level of the soil there would be a great increase in yield and at the same time the value of the

corn grain as feed would be increased. Through a balanced condition for both nitrogen and phosphorus fertilizers in the soil these values could be obtained.

## VITA

The author was born in Columbia, Missouri, on January 24, 1921. His elementary and secondary school education was received in the Columbia Public Schools. In 1939 he entered the College of Agriculture, University of Missouri, and in 1943 received the Bachelor of Science degree.

During the years 1943-46 he was a member of the United States Army in World War II serving in the capacity of an Officer in the Field Artillery and Combat Infantry Units. One year of this time he spent in Germany.

Upon discharge from the Army in 1946, he began graduate study in the Division of Soil Fertility in the Department of Agronomy, University of Illinois. He received the Master of Science degree in June, 1948. While completing the requirements for the Doctor of Philosophy degree, he was employed half-time as a Special Research Assistant.

The author is a member of Sigma Xi, Gamma Alpha, Gamma Sigma Delta, and Phi Kappa Phi.